CAP subsidies and productivity of the EU farms

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Abstract

The paper investigates the impact of the Common Agricultural Policy (CAP) subsidies on farm total factor productivity (TFP) in the European Union (EU). We employ a structural semi-parametric estimation algorithm directly incorporating the effect of subsidies into a model of unobserved productivity. We empirically study the effects using the Farm Accountancy Data Network (FADN) samples for the EU-15 countries. Our main findings are clear: subsidies impact negatively farm productivity in the period before the decoupling reform was implemented; after decoupling the effect of subsidies on productivity is more nuanced and in several countries it turned positive.

Key words: CAP subsidies, investment, productivity, micro data, EU farms

JEL Classification: D22, D24, Q12, Q14, Q18

1 Introduction

Annually, EU spends around €50 billion on the Common Agricultural Policy (CAP) with the primary goal to support farmers' income and improve the environmental impact of agricultural production. The majority of CAP subsidies are disbursed in the form of decoupled direct payments from the EU budget which are not linked to current and future quantities of agricultural production. Within the CAP there are also subsidies which are coupled to the production of

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specific crop or animal commodities or allocated for rural development projects. Various studies have shown that these CAP subsidies impact on the farm sector productivity.

There are two competing policy relevant arguments regarding the impact of agricultural subsidies on productivity. On the one hand, in the context of the World Trade Organization (WTO) trade liberalization agenda, the discussion centres on the distortionary impact of subsidies on agricultural markets (including on productivity) and how the effects differ between different types of subsidies. Following the WTO agreements, many countries decoupled their agricultural subsidies with the aim of reducing distortionary agricultural support (Meléndez-Ortíz et al., 2009).[2,3] On the other hand, recent developments in world markets leading to increasing volatility of global food commodity prices and rising food security concerns, especially in developing countries, have led to calls for maintaining agricultural support, stimulating farm investment and the adoption of productivity enhancing modern technology (FAO, 2011). The European Commission explicitly mentions in its proposal for the post-2013 CAP the challenge of food security and the EU's goal to support long-term food supply potential and meet the growing world food demand(European Commission, 2010; 2011).

The impact of subsidies on agricultural production, input allocation and income distribution is well documented in the literature (e.g., Alston and James, 2002; Ridier and Jacquet, 2002; Lagerkvist, 2005; Goodwin and Mishra, 2006; Serraet al., 2006; Sckokai and Moro, 2009; Vercammen, 2007; Féménia et al., 2010; Carpentier et al., 2012; Weber and Key, 2012), but significantly less attention has been devoted to the impacts of subsidies on productivity of farms. Theoretical studies suggest that subsidies may have positive impact on farm production and at the same time negative impact on farm productivity (Hennessy, 1998; Ciaian and Swinnen, 2009). However, these studies are inconclusive in predicting the exact relationship between agricultural

[2]The Eastern enlargement and budgetary problems of the EU have also affected decoupling of farm subsidies.

[3]Several studies argue that even decoupled subsidies may still affect production decisions and productivity of farms (Lagerkvist, 2005; Ahearn et al., 2006; Goodwin and Mishra 2005, 2006; Vercammen, 2007; Key and Roberts, 2009; Whitaker, 2009, Ciaian and Swinnen, 2009, Bhaskar and Beghin, 2010; Carpentier et al., 2012).

subsidies and productivity while the empirical literature finds mixed effects. The existing empirical studies usually employ a two stage approach whereby productivity measures are estimated in the first stage without controlling for subsidy effects and then these productivity measures are regressed on subsidies in the second stage(e.g., Giannakas et al., 2001; Latruffe et al.,2009; Lakner, 2009; Sauer and Park, 2009; Zhu and Oude Lansink, 2010; Mary 2012); Kumbhakar and Bokusheva(2009) and Latruffe et al. (2011) are exceptions. The disadvantage of the two stage approach is that it does not incorporate subsidies explicitly into a structural estimation algorithm and thus cannot capture their full effect on productivity. The two-stage approach therefore may lead to biased estimates of the overall impact of subsidies on productivity.

We aim to fill this gap in the literature by investigating the impact of CAP subsidies on (aggregate) farm productivity using a structural productivity estimation approach based on Olley and Pakes (1996).We explicitly model the unobserved productivity and directly incorporate the effects of subsidies into a structural semi-parametric estimation procedure.We apply the procedure to the Farm Accountancy Data Network (FADN) dataset and estimate total factor productivity (TFP)[4] for large and representative samples of farms in each of the EU-15 countries over the period 1990-2008.Furthermore, special attention is paid to the significant change of regime with decoupling of subsidies by the 2003 CAP reform. The paper compares the impact of subsidies on farm productivity before and after decoupling. We find that subsidies are negatively associated with productivity until the implementation of the decoupling reform. After this reform the link between subsidies and farm productivity became more nuanced as in several EU-15 countries it turned positive. From a policy perspective the finding is important at least in the EU

[4] In this paper, as in Olley and Pakes (1996), we define TFP as the (Solow) residual estimated from a production function where the change in TFP represents the vertical shift of the production function. TFP change can be decomposed into technological change and the (technical and scale) efficiency with which known technology is applied to production relative to the “best practice” production function (frontier). Although technological change and technical efficiency share a common methodological basis in the production function, applied work in these fields has evolved largely independently. Latruffe (2010) provides detailed review of productivity and efficiency concepts and measures applied in agriculture related research. Van Biesebroeck (2008) investigating five estimators from a variety of productivity literatures in a consistent framework demonstrates that the productivity measures are similar across methods (the correlations between the different productivity levels and changes are invariably high) and, to a large extent, the different productivity estimators lead to the same conclusions. We note that our goal in the paper is not to reconcile concepts and measurement approaches but to merely obtain unbiased and consistent estimates of TFP as defined above.

context, especially following the recent European Commission proposals that the EU subsidy system is likely to continue after 2013.

The paper is organised as follows. Next, we review the relevant theoretical and empirical literature and motivate our empirical approach. In section 3 we present our estimation algorithm. In section 4 we describe the FADN data and report production function estimation results. In section 5 we verify the link between subsidies and farm productivity by the means of correlation analysis. Section 6 summarises our findings and concludes.

2 Subsidies and productivity: Findings inthe literature

Theoretical studies show that there are various channels through which subsidies impact (aggregate) productivity (De Long and Summers, 1991; Blomstrom et al., 1996; Rajan and Zingales, 1998). Subsidies may either increase or decrease productivity and thus the net effect may be either positive or negative. The negative impact of subsidies on productivity may result from *allocative and technical efficiency losses* due to distortions in production structure and factor use, soft budget constraints and the shift of subsidies to less productive enterprises. The positive impact of subsidies may be due to *investment-induced productivity gains* caused by interactions of credit and risk attitudes with subsidies (subsidy-induced credit access, lower cost of borrowing, reduction in risk aversion, increase in productive investment).

Subsidies may negatively affect farm productivity because they distort the production structure of recipient farms leading to allocative inefficiency. Recipient farms may modify their behaviour and start investing in subsidy seeking activities which are relatively less productive (Baumol, 1990; Alston and James, 2002). Allocative inefficiency may also be a result of distortions in input use. Subsidies give recipient farms an incentive to change their capital-labour ratio which can lead to allocative inefficiency, i.e., over-investment in subsidised inputs. Subsidisation may also give rise to technical inefficiency if they are captured by the farms as higher profits leading to slack, lack of effort and competitive pressures to seek cost-improving methods (Leibenstein, 1966). Similarly, Kornai (1986) argues that subsidisation might give rise to soft budget constraints which would lead to inefficient use of resources. If the budget constraint is hard the farm will continuously adjust to (unfavourable) external conditions by behaving in an entrepreneurial manner. If the budget constraint is soft, productive efforts are no longer imperative; the subsidy provider acts like an insurer taking over the moral hazard while the insured (recipient farms) are less careful in protecting their wealth. Finally, subsidies may end up being transferred to less productive farms by policy makers "with special interest", or as Olson (1982) asserts, subsidies may reduce the rate at which resources are reallocated from one activity to another in response to new technologies or market conditions.

The literature on credit constraints and risk behaviour in agriculture (e.g., Blancard et al., 2006; Ciaian and Swinnen, 2009; Kumbhakar and Bokusheva, 2009; Hüttel et al., 2010) asserts a positive relationship between subsidies and productivity. If farms are credit rationed, then subsidies may provide an additional source of finance either directly by increasing farms' financial resources or indirectly through the improved access to formal credit. In other words, for credit rationed farms subsidies may serve as a substitute for credit. Studies find that credit constraint farms invest less and have lower allocative and technical efficiency which would improve as a result of subsidies (Feder,1985; Feder et al., 1990, and more recently Blancard et al., 2006; Kumbhakar and Bokusheva, 2009; Hüttel et al., 2010). Cheaper credit would stimulate investments and input use thus leading to improved farm performance. Credit unconstrained farms may also be affected, if subsidies present a cheaper source of financing than the credit available from the financial markets. Furthermore, Hennessy (1998) suggests that under uncertainty subsidies affect markets through a wealth effect; subsidies affect farmers' wealth and thus their risk attitudes. For example, farmers may be more willing to expand production with certain type of activities or employ additional factors which would otherwise be viewed as too risky (Roche and McQuinn, 2004).

The negative effect of subsidies (*allocative and technical efficiency loss*) is likely negatively correlated with decoupling, whilst the positive effect (*investment-induced productivity gain*) is likely positively correlated. Consequently, we expect that coupled subsidies will have a smaller positive or a larger negative impact on productivity relative to decoupled subsidies. First, the efficiency loss is likely to be stronger for coupled subsidies than for decoupled ones because farm eligibility for coupled payments is directly linked to farm factor and production decisions, and thus are likely to lead to distortions in input and/or output allocation. Coupled subsidies may motivate farmers to expand subsidised activities at the expense of otherwise more productive activities. For the decoupled subsidies the link to farm activities is weaker. Farms receive CAP decoupled subsidies irrespective of their production decisions, so the subsidies are less likely to induce allocative and technical inefficiency effects(Floyd, 1965; Dewbre et al., 2001; Alston and James, 2002; Guyomard et al., 2004; Courleux, et al., 2008).[5]Second, the investment-induced productivity gain through the credit and risk channels is likely smaller for coupled than for decoupled payments (e.g., Ciaian and Swinnen, 2009; Hennessy, 1998). The conditionality of coupled subsidies increases monitoring costs of financial institutions if subsidies are used by credit constrained farms as collateral for investment loans. Financial institutions have to check what farms produce to learn about their future eligibility for coupled subsidies. For decoupled payments, the certainty of payments is higher due to their link to land assets which are relatively costless to monitor and less a subject to production risk. Thus decoupled payments are more suitable as collateral to financial institutions (Barry and Robinson, 2001; Ciaian et al., 2012).

Findings in the empirical literature are mixed and inconclusive although negative relations between CAP (coupled) subsidies and various measures of productivity tend to prevail. In general, studies focus on the effects of coupled subsidies in narrowly defined agricultural sectors. Latruffe et al. (2009) find a negative impact of coupled CAP subsidies on managerial efficiency of French farms specialised in cereals, oilseeds and beef production. Lakner (2009) shows that the agri-

[5] The recipients of the decupled payment need to fulfil only the so-called cross-compliance conditions which means that to get subsidies, among others, farms need to fulfil certain agri-environmental conditions. .

environmental payments and investment programmes have negative effects on the technical efficiency of organic dairy farms in Germany. Estimates of Zhu and Oude Lansink (2010) indicate that negative technical efficiency effects of coupled subsidies prevail for crop farms in Germany, the Netherlands and Sweden. Similarly, Zhu et al. (2012) find that both output-related and input-related CAP subsidies have negative impact on dairy farm technical efficiency in Germany and the Netherlands between 1995 and 2004, but no significant impact in Sweden. Their results also imply that a higher degree of coupling in farm support negatively affects farm efficiency. Latruffe et al. (2011) report a negative impact of total subsidies on dairy farms' technical efficiency in seven EU countries (Denmark, France, Germany, Ireland, Spain, the Netherlands, and the UK) during the period 1990-2007. Latruffe et al. (2011) also study the first years of decoupled payments and their results indicate that in all countries, except Denmark, the average technical efficiency surprisingly was lower after decoupling.

In contrast, Sauer and Park (2009) find a positive influence of organic subsidies on TFP change (technical efficiency change and technological change) for organic dairy farms in Denmark during the period 2002-2004. Yee et al. (2004) also find positive relation between TFP of US farms and subsidies but of somewhat different kind – the public expenditure on investment in research, extension and infrastructure. Mary (2012) estimates the impact of various types of CAP subsidies on French crop farms' TFP during the period 1996-2003. The coupled CAP payments (i.e., set-aside premiums, Less Favoured Area (LFA) payments, and livestock subsidies) are found to have a negative impact on TFP. In contrast, targeted coupled subsidies which are not automatic but subject to project approval, such as investment and agri-environmental measures, are found to have no significant impact on TFP. Furthermore, Mary (2012) finds that the Agenda 2000 reform (i.e., partial decoupling) had a positive impact on aggregate productivity.

3 Estimation strategy: Linking productivity and subsidies

3.1 Behavioural framework

Our strategy for estimating productivity is built on the Olley and Pakes (1996) approach which entails modelling unobserved productivity (TFP) while directly controlling for the effects of subsidies in the estimation algorithm.[6] The strength of the approach lies in its flexibility in accommodating the specificities of the economic problem of interest and its efficiency in dealing with estimation biases. First, it allows us to control for the classic simultaneity bias (Marshak and Andrews, 1944) when estimating production functions, without having to rely on instruments. This is important as we do not have good instruments available. The second advantage is that we can control for potential selection bias due to non-random exits.

We extend the Olley and Pakes (1996) algorithm by explicitly allowing farm decisions and market environment (factor markets and demand conditions) to be affected by the CAP subsidies which we directly introduce into the underlying structural model of the farm. The single period profit function of farm, j at time, t is $\pi(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}) - c(i_{jt}, s_{jt}, \vec{e}_{jt})$, where k_{jt}, and ω_{jt} are the logs of farm's state variables, capital (including land) and (unobserved) productivity respectively, while i_{jt} is the log of farm's investment. Both restricted profit, $\pi(.)$ and adjustment cost, $c(.)$ depend also on farm subsidies s_{jt} and $\vec{e}_{jt}$ which represents the economic environment that farms face at a particular point in time; $\vec{e}_{jt}$ captures effects of input prices, demand conditions and industry characteristics. As in Olley and Pakes (1996) all these factors are assumed to change over time as some factors are also farm specific.

The incumbent farm maximizes its expected value of both current and future profits according to:

$$V(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}) = \max\begin{cases} \Phi(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}), \\ \max_{i_{jt}}\{\pi(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}) - c(i_{jt}, s_{jt}, \vec{e}_{jt}) + \\ \beta E[V(k_{jt+1}, s_{jt+1}, \omega_{jt+1}, \vec{e}_{jt+1}) \mid k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}, i_{jt}]\}. \end{cases} \quad (1)$$

[6] We do not estimate the effect of any particular channel through which subsidies interact with productivity; we estimate the net effect of allocative and technical efficiency loss and the investment-induced productivity gain caused by subsidies.

The Bellman equation explicitly considers two farm decisions. First is the exit decision; $\Phi(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt})$ represents the sale value of the farm. Second is the investment decision i_{jt}, which solves the interior maximization problem. Under the assumption that equilibrium exists and that the difference in profits between the farm continuing and exiting is increasing in ω_{jt} we can write the optimal decision rule of a farm to remain in production as

$$\mathrm{X}_{jt} = \begin{cases} 1 \quad if \quad \omega_{jt} \geq \overline{\omega}_t(k_{jt}, s_{jt}, \vec{e}_{jt}) \\ 0 \qquad\qquad otherwise \end{cases} \tag{2}$$

and the investment demand function as

$$i_{jt} = i_t(k_{jt}, s_{jt}, \omega_{jt}, \vec{e}_{jt}) . \tag{3}$$

The threshold function $\overline{\omega}_t(.)$ as well as $i_t(.)$ is determined as part of the Markov perfect Nash equilibrium in decisions (Ericson and Pakes, 1995; Olley and Pakes, 1996) and depends on the state variables and the characteristics of the economic environment, including subsidies and factor prices. In the context of the CAP, farm capital stock might be related to the level of subsidies received which may result in higher or lower capital intensity (capital/labour ratio). By incorporating the subsidies information into the investment demand and exit rule explicitly, we can better control for differences in market conditions than when only controlling through the capital stock. Conditional on staying in production the farm has to decide about its inputs, labour (*l*) and materials (*m*) use and investment (*i*). Investment determines the capital stock at the beginning of each period. The law of capital accumulation is given by $k_{jt} = (1-\delta)k_{jt-1} + i_{jt-1}$, where δ is depreciation rate of capital.

As in Olley and Pakes (1996) we assume that investment is monotonically increasing in productivity conditioned on the level of subsidies received.[7] Pakes (1994) discusses the conditions under which the investment demand function is strictly monotonic in ω_{jt}. Abel and Eberly (1994) and several related papers, in a slightly different context, extend the analysis of

[7] The monotonicity needed in Olley and Pakes (1996) only requires the marginal product of capital to be increasing in productivity. In fact, we argue here that the subsidy crucially improves monotonicity in the relationship between investment and productivity (in line with findings by De Long and Summers, 1991 and Rajan and Zingales, 1998).

monotonicity of investment and disinvestment regarding firm fundamentals and show that monotonicity breaks only at zero investment values.[8] Recently Hüttel et al. (2010) apply this result to investment analysis of the German farm. Given monotonicity, investment can be inverted to generate the productivity function

$$\omega_{jt} = h_t(i_{jt}, k_{jt}, s_{jt}, \vec{e}_{jt}) . \tag{4}$$

Furthermore, as in Olley and Pakes (1996) productivity is assumed to evolve according to a first-order Markov process with transition probability $p(\omega_{jt} \mid \omega_{jt-1})$ and to be determined by a set of distributions conditional on the information at time *t* which includes past (realised) productivity shocks. Given this distribution set, both the exit and investment decision will crucially hinge upon farm's perception of the distribution of the future market structure given current information (past productivity). The decisions that farms take will in turn generate a distribution for the future market structure (Maskin and Tirole, 1988).

3.2 Estimation algorithm

Our estimation algorithm is similar to the one in Olley and Pakes (1996) except for the fact that the first stage estimation and the survival equation include the subsidy variable and additional economic environment controls (similar to Rizov and Walsh, 2009 and 2011).[9]In this way we have introduced subsidies as an additional control in the state space of the dynamic program of the farm. The production function we estimate is specified as

$$y_{jt} = \beta_0 + \beta_m m_{jt} + \beta_l l_{jt} + \beta_k k_{jt} + \omega_{jt} + v_{jt} , \tag{5}$$

where y_{jt} is a log of gross real output and v_{jt} is a random error term with a zero mean.

Substituting the productivity (inverted investment demand) function (4) into the production function (5) gives us:

[8] We note that observations with zero net investment represent a very small proportion (between 0.5 and 3.3 percent) in every country sample that we use in our empirical analysis.
[9] The market environment control vector $\vec{e}_{ji}$ includes farm specialisation, location information at NUTS3 (Nomenclature of Territorial Units for Statistics) level and a time trend, capturing technology and price effects.

$$y_{jt} = \beta_0 + \beta_m m_{jt} + \beta_l l_{jt} + \beta_k k_{jt} + h_t(i_{jt}, k_{jt}, s_{jt}, \vec{e}_{jt}) + \nu_{jt} \,. \quad (6)$$

In Equation (6) as in Olley and Pakes (1996) the productivity function $h_t(.)$ is treated non-parametrically using a polynomial. The non-parametric treatment, however, results in collinearity and requires $h_t(.)$, k_{jt}, and the constant to be combined into a function $\phi_t(i_{jt}, k_{jt}, s_{jt}, \vec{e}_{jt})$ such that Equation (5) becomes

$$y_{jt} = \beta_m m_{jt} + \beta_l l_{jt} + \phi_t(i_{jt}, k_{jt}, s_{jt}, \vec{e}_{jt}) + \nu_{jt} \,, \quad (7)$$

which forms the first stage of our estimation algorithm and is estimated using OLS. In Equation (7) subsidies are allowed to interact with the terms of the polynomial in capital and investment.[10]

In the first stage of the estimation algorithm we can only identify materials and labour coefficients while the capital coefficient has to be identified in the second stage. As in Olley and Pakes (1996) farm labour is treated as a variable and non-dynamic input, which is a function of the state variables including subsidies and for which decisions are always made during the current period – an assumption introducing additional variation in the labour demand (Ackerberg et al., 2007). Materials are also treated as fully variable and non-dynamic input on which decisions are always made after labour is chosen and given the contemporaneous realisation of productivity.[11]In the first stage we also estimate $\hat{\phi}_t$ which allows us to express ω_{jt} for use in the second stage as

$$\hat{\omega}_{jt} = \hat{\phi}_{jt} - \beta_0 - \beta_k k_{jt} \,. \quad (8)$$

Note that the first stage is not affected by endogenous selection because ϕ_t fully controls for the unobserved productivity, while by construction, ν_{jt} represents unobserved factors that are not known by the farmer before investment and exit decisions are made. In contrast, the second stage

[10] In addition, to control for the nature of the subsidies, we use a dummy variable capturing the effect during the period after decoupling of subsidies which was actually implemented in 2005/2006 across the EU-15. We fully interact the dummy with the terms of the polynomial in the first stage estimation equation.

[11] We consider demand for materials, similar to labour demand, to be a function of the state variables and subsidies. In addition, we assume that labour also affects demand for materials: $m_{jt} = m_t(\omega_{jt}, k_{jt}, s_{jt}, l_{jt}, \vec{e}_{jt})$; thus, the timing of decisions on labour and materials demands differs within each period. We note that the partial dependence of materials on labour demand brings additional variation which breaks the possible collinearity with the non-parametric function in Equation (7) given that productivity is not static but rather evolves throughout each period.

of the estimation algorithm might be affected by endogenous selection because the exit decision in period t depends directly on ω_{jt}.

To clarify the timing of production decisions and their impact on the selection bias we decompose ω_{jt} into its conditional expectation given current information (past productivity) and a residual: $\omega_{jt} = E[\omega_{jt} \mid \omega_{jt-1}] + \xi_{jt} = g(\omega_{jt-1}) + \xi_{jt}$. By construction ξ_{jt} is uncorrelated with information in t-1 and thus with k_{jt} which is chosen prior to time t. Note that the farm's exit decision in period t depends directly on ω_{jt} and thus the exit decision will be correlated with ξ_{jt}. This correlation relies on the assumption that farms exit production quickly, in the same period when the decision is made. If exit is decided in the period preceding actual exit, then even though there is a selection *per se*, exit would be uncorrelated with ξ_{jt}. To account for endogenous selection on productivity we extend the g(.) function as in Olley and Pakes (1996):

$$\omega_{jt} = g'(\omega_{jt-1}, \hat{P}_{jt}) + \xi_{jt}, \qquad (9)$$

where $\hat{P}_{jt}$ is the estimated survival propensity score which controls for the impact of selection on the expectation of ω_{jt}, i.e., there is a trade-off such that farms with lower survival probabilities which do in fact survive to time t likely have higher ω_{jt-1} than those with higher survival probabilities. We estimate $\hat{P}_{jt}$ non-parametrically using a Probit model with a polynomial approximation. Note that we condition farm exit on the state variable set extended again with information on subsidies and the economic environment.[12]

The capital coefficient is identified in the second stage of our estimation algorithm. Substituting equations (9) and (8) into equation (5) gives us

[12] In our FADN data exit from the sample is affected not only by the decision of the farm to exit production as described in our behavioural framework but also by the survey design and selection rules. Given the possibility that FADN selection rules might not be random but affected by farm productivity and allocation of subsidies controlling for selection remains important. FADN selection rules might not be random because they depend on the importance of farm types in total population. For example, if the importance of a certain farm type decreases in total population then also the number of these farms in the FADN sample will be reduced. This is done to preserve the representativeness of the FADN sample. If the exit is in fact random then the selection correction is still perfectly valid; it just would not affect the estimates as Ackerberg et al. (2007) assert. We acknowledge the FADN data limitations regarding analysis of the farm exit decision.

$$y_{jt} - \hat{\beta}_m m_{jt} - \hat{\beta}_l l_{jt} = \beta_k k_{jt} + g'(\hat{\phi}_{jt-1} - \beta_k k_{jt-1}, \hat{P}_{jt}) + \varepsilon_{jt}, \tag{10}$$

where the two β_0 terms are encompassed into the non-parametric function, *g'*(.) and ε_{jt} is a composite error term comprised of ν_{jt} and ξ_{jt}. The lagged $\hat{\phi}_{jt-1}$ variable is obtained from the first stage estimates at the*t*-1 period. Because the conditional expectation of ω_{jt} given current information depends on ω_{jt-1}, we need to use estimates of $\hat{\phi}$ from the*t*-1 period. Equation (10) is estimated by a non-linear least squares (NLLS) search routine approximating *g'*(.) with a polynomial.[13]

Similar to Olley and Pakes (1996) we use the estimated (consistent) production function coefficients to obtain unbiased farm-specific, time-varying total factor productivity (*tfp*) measures as residuals from the production function:

$$tfp_{jt} = \exp(y_{jt} - \hat{\beta}_m m_{jt} - \hat{\beta}_l l_{jt} - \hat{\beta}_k k_{jt}). \tag{11}$$

Clearly, the two-stage estimation algorithm has an impact on the estimated production function coefficients. Compared to OLS estimator we expect materials and labour coefficients to be lower since materials and labour demands are strongly positively correlated with the productivity shock. The direction of the bias in the capital coefficient is less clear since it impacts both through the selection equation and directly, through the productivity shock. However, the variation in the capital stock that is attributed to the variation in output – purified from the variation in materials and labour – is now conditioned on the subsidy level received by the farm and (other) economic environment controls. Due to positive correlation between regional productivity and the subsidy level, farms receiving higher per unit of labour subsidy – on average – obtain higher output level which, indirectly, through the credit channel may lead to higher

[13] Woodridge (2009) presents a concise, one-stage formulation of the original Olley and Pakes (1996) algorithm using GMM estimator which is more efficient but less flexible than the standard Olley-Pakes methodology.

capital intensity.[14] If farms are credit rationed, then subsidies may substitute for missing credit and thus stimulate capital investments (Ciaian and Swinnen, 2009; Kumbhakar and Bokusheva, 2009; Hüttel et al., 2010) leading to a positive relationship between productivity, subsidy level and capital intensity. Therefore in order to recover the correct estimates of the production function, it is important to control for the effect of subsidies that works both through the instantaneous productivity shock impacting materials and labour demand and over time through the capital accumulation process. Thus, the resulting *tfp* measures are obtained while controlling for the fact that market conditions are different and evolve differently given the level and nature of subsidies received by farms.[15]

4 Data and productivity estimates

We apply our estimation algorithm to the Farm Accountancy Data Network (FADN) country samples, which are compiled and maintained by the European Commission. FADN is a European system of sample surveys that take place each year and collect detailed structural and accountancy data on the EU farms. In total there is information about 150 variables on farm structure, yields, outputs, inputs, costs, incomes, subsidies and taxes, and various other financial variables. FADN is the only source of micro-economic data that is harmonised as the accounting principles are the same across all EU Member States. FADN is representative of the commercial agricultural holdings in the whole of the EU(EU DG-AGRI, 2010). Holdings are selected to take part in the surveys on the basis of sampling frames established at the level of each region in the EU. The yearly FADN samples cover approximately 80,000 farms and about 90 percent of the utilised agricultural land in the EU-27.

[14] CAP subsidies are not assigned randomly to farms but depend on regional productivity levels. Farms located in more productive regions receive higher subsidies than farms located in less productive regions. Historically, this is related to the coupled subsidies as their value was determined by regional yields and animal heard sizes. With the 2003 CAP reform, coupled subsidies were decoupled from production but the regional variation in subsidies was largely preserved (Ackrill, 2000; European Commission, 2012).

[15] More highly subsidised farms might experience faster technological change. Therefore, we check whether technological change is affected by the level of subsidies by interacting time trend with subsidies, in addition to the fully interacted polynomial. The results are not different from the reported in the paper.

The panel we employ in the study covers the period 1990-2008 and includes the commercial farms defined as in Sckokai and Moro (2009) in all EU-15 countries.[16] Our goal is to estimate unbiased and consistent total factor productivity (TFP) measures at farm level, within six (FADN) farm-type samples, for each country, and to document the aggregate productivity levels and changes over time and by farm type.[17]Furthermore, our ultimate goal is to estimate the link between CAP subsidies and farm TFP. The strategy of our empirical analysis implies that we run regressions within the six farm-type samples for each country which leaves us with 83farm-type country samples, with sufficient number of observations to apply our estimation algorithm. The estimated samples account for about 85 per cent of the FADN EU-15 farms.

- Table 1 here -

Summary statistics for the regression variables are reported in Table 1 and detailed definitions based on the FADN (2010) codebook are presented in an on-line Appendix 1. The summary statistics show substantial heterogeneity of (average) farms across the EU-15. There is some evidence of a North-South divide but with several exceptions when various indicators are considered. In Germany, the Netherlands and Denmark farms are more capital intensive (have higher capital/labour ratio) and invest more; these farms are also the largest in terms of output. Not too different from this group of countries is Italy where farms are also relatively large in terms of capital and investment but less so in terms of output. The Greek and Portuguese farms are the least capital intensive, invest the least and are the smallest in terms of output. Farm employment varies less compared to capital across the EU-15 countries with farms in the Netherlands, the UK and Germany appearing the largest in terms of labour employed.

There is even more pronounced North-South differentiation between the Member States when average subsidies per farm are considered, which is largely determined by the differences in farm size. For north European countries average farm subsidies range roughly between

[16] For Austria, Finland and Sweden which joined the EU in 1995 the period of analysis is 1995-2008.
[17] The six farm types comprise field crop farms, horticultural and vine farms, specialised dairy farms, other grazing livestock farms, poultry and pig meat farms, and mixed farms.

€16,000 and €35,000 (the highest subsidies being paid to Finish farms) while for south European countries subsidies are around or less than €8,000 per farm. This relationship holds also for subsidy per unit of labour employed. However, when subsidy per unit of capital is considered the picture is the opposite – south European farms are more heavily subsidised.

- Table 2 here -

In Table 2 the production function coefficients estimated from the 83samplesare presented for each EU-15 Member State by aggregating over farm types using output shares as weights (an on-line Appendix 2 reports the coefficients by farm type). There is substantial variation across countries as the materials coefficient ranges between 0.59 for Greece and 0.87 for Sweden; the labour coefficient ranges between 0.07 for Ireland and 0.26 for Spain and Denmark; and the capital coefficient is between 0.05 for Ireland and 0.12 for Austria. Farms in most, especially north European, countries exhibit constant or increasing returns to scale, while the farms in Greece and Italy are characterised by slightly decreasing returns. The (aggregated) Adjusted R^2 from the second stage of the estimation algorithm is high, above 0.90 for every country set of regressions suggesting high goodness of fit.[18]

In the last column (6) of Table 2, both a productivity index (relative level) and a growth rate are reported for each EU-15 country. These two aggregate productivity measures (TFP index and TFP growth) are weighted averages of farm-level productivity measures using output shares as weights, within and between farm types, thus capturing the farm and sector composition effects. As explained by Van Biesebroeck (2008) productivity is intrinsically a relative concept.

[18] We carry out several econometric tests at the first and the second stage of our estimation algorithm. At the first stage, we run Wald tests for the joint significance of all the polynomial terms and reject the null of no difference from zero at 1 percent level in all regressions. Second, Ramsey specification-error tests for omitted variables were run and the null that the models had no omitted variables was not rejected at conventional levels in any regression. Third, Breusch-Pagan tests for heteroskedasticity of the errors were run and the null of constant variance was not rejected at conventional levels in any regression. Forth, Breusch-Godfrey tests for first- and second-order serial correlation in the errors were also run and the null of no serial correlation was not rejected at conventional levels in any regression. Finally, as in Olley and Pakes (1996) we conducted Hausman tests to investigate the differences between the standard OLS and FE coefficient estimates and those obtained from our estimation algorithm. The χ^2 statistics rejected the nulls that any of the OLS or FE models were correct at 5 percent level in all samples.

Therefore, for comparative purposes, within each EU-15 country, we define our farm productivy measure in (relative) levels following Olley and Pakes (1996) as $TFP_{jt} = tfp_{jt} / \overline{tfp_t}$, where $\overline{tfp_t}$ is the average productivity of all farms in period t; the farm productivity growth is defined as $\Delta tfp_{jt} = \log(tfp_{jt} / tfp_{jt-1})$.

The TFP index (TFP_{jt}) ranges between 0.73 in Greece and 1.67 in Finland; a higher index suggests that relatively more productive farms and farm sectors dominate, i.e., they have larger market shares. Overall, by this measure, the north European countries appear to have more productive farm sectors. The comparison of the TFP growth (Δtfp_{jt}) measures is interesting; average annual growth ranges between -0.78% in Finland and +2.05% in Italy. Six small, north European countries show negative productivity growth while the three largest EU-15 countries, Germany, France and the UK all show small but positive productivity growth. The highest average annual productivity growth is recorded by the south European countries, Italy, Portugal and Spain.

5 The subsidies and productivity link: A correlation analysis

Our goal in this section is to test the link between subsidies and farm productivity. Subsidies are widely used in the EU agriculture and the large majority of farms have received subsidies in one way or another. Thus, we do not have an easy way to identify treatment and control groups. Furthermore, we are interested here in the link between subsidies and productivity at the aggregate (country) level. Therefore, we test the relationship by the means of correlation analysis using the same FADN country samples that we used to estimate farm productivity (tfp_{jt}). We note that this verification analysis is different from the two-stage analysis in previous productivity studies because in our productivity estimation algorithm we have already explicitly accounted for the effects of subsidies. Thus, to demonstrate the link between subsidies and our productivity measure it is sufficient to use a simple nonparametric correlation analysis.[19]

Spearman (rank) correlation coefficient or Spearman's ρ is a nonparametric measure of statistical dependence between two variables. It assesses how well the relationship between two variables can be described using a monotonic function. If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. The Spearman correlation coefficient is often described as being "nonparametric" because compared with the Pearson correlation, which only gives a perfect correlation when two variables X and Y are related by a linear function, a perfect Spearman correlation results when X and Y are related by any (unrestricted) monotonic function. Furthermore, Spearman correlation exact sampling distribution can be obtained without requiring knowledge of the parameters of the joint probability distribution of X and Y. The sign of the Spearman correlation indicates the direction of association between X and Y. A Spearman correlation of zero indicates that there is no tendency for Y to either increase or decrease when X increases. The Spearman correlation increases in magnitude as X and Y become closer to being perfect monotone functions of each other.

- Table 3a here –

- Table 3b here –

In Table 3a we report results from the correlation analyses for the full samples, by country, before and after decoupling was introduced. In Table 3b we report analogous results but for subsamples where farms receive only coupled subsidies, which were most severely affected by the policy change (e.g., crop area payments, animal payments). That is we drop from the sample farms that received other type of coupled subsidies which were not subject to decoupling and included mainly rural development payments (e.g., agri-environmental payments, investment

[19] We also carried out multivariate regression analysis on the link between subsidies and productivity using specification based on the productivity function (Equation (4)), by country. The results of this conditional analysis are consistent with the unconditional correlation analysis results reported in the paper, and are available on request.

payments, LFA payments). The share of farms that remained for the analysis of the subsamples varies between 76 percent in Greece and 43 percent in Sweden. We expect that the effect of decoupling will be stronger in this subsample because we eliminate the potential impact that other coupled subsidies (those not directly affected by decoupling) may have on the farm productivity. Other coupled subsidies may bias upward or downward the estimated impact of subsidy decoupling on productivity as they may either increase (e.g., investment payments) or reduce (e.g., agri-environmental payments) productivity.

Based both on the full samples and the subsamples, we find clear evidence that the link between subsidies and the level of productivity (tfp_{jt}) before decoupling is negative even though the magnitude of the correlation coefficients varies substantially across countries; often coefficients are quite small but nevertheless the correlations are highly statistically significant. Exceptions are Denmark and Portugal where productivity shows consistently positive correlation with subsidies. In terms of productivity growth (Δtfp_{jt}) the correlation is also negative for majority of countries as for only four countries it is positive but not statistically significant at conventional levels. These results are consistent with findings by previous productivity studies which employ two-stage approaches to identify the CAP subsidy impact on farm technical efficiency (e.g., Latruffe et al., 2009; Lakner, 2009; Zhu and Oude Lansink, 2010, Mary, 2012).

Considering the full sample results reported in Table 3a, for the period after decoupled subsidies were introduced the relationship between subsidies and farm productivity appears more diverse as for all countries with significant correlations the coefficients became less negative. Furthermore, besides for Denmark and Portugal, the correlation became (weakly) positive for three more countries – Austria, Finland and Sweden. Importantly, the correlation of subsidies with productivity growth has changed dramatically. For majority of countries the correlation coefficients turned positive as they are significant at the 5 percent level for nine countries. Only for Greece the coefficient remained negative but not statistically significant. Interestingly, the group of countries for which a switch of the correlation sign occurred, from negative to positive, after decoupling is mixed, including both north and south European Member States.

When considering the subsample results reported in Table 3b the most important observation is that the magnitudes of change following subsidy decoupling are larger compared to those in the full samples. Furthermore, productivity growth rates and subsidies are positively correlated in every country after the decoupling policy was introduced. The effects in the subsamples compared to the full samples clearly suggest that indeed decoupling had an impact on productivity. Our findings are consistent with Zhu et al. (2012) and Mary (2012),neither of which investigate the fully decoupled payments but consider the impact of partial decupling (e.g., the introduction of the Agenda 2000). The former study finds that a higher degree of coupling in farm support negatively affects farm efficiency, whereas the latter study finds that the Agenda 2000 reform had a positive impact on productivity.

Clearly the link between productivity and subsidies depends on their type. Our results provide (indirect) evidence that coupled subsidies indeed distort farm behaviour (e.g., production structure and/or input allocation) leading to productivity loss. Furthermore, due to the allocative and technical inefficiencies, monitoring costs and payment uncertainty, coupled subsidies are expected to stimulate less credit and hence also enhance less productive investment compared to decoupled payments. Also note that a significant part of coupled payments could be leaked away to other agents through changes in market prices; the effect diminishes farms' benefits from subsidies. The leakage is positively correlated with coupling because it implies stronger link of subsidies to farm activities and thus stronger impact on the aggregate price level (Floyd, 1965; Alston and James, 2002).

Compared to coupled subsidies, the results indicate that in countries where positive effects are observed, decoupled subsidies may impact farm productivity through the "credit channel". Subsidies allow farms to improve their credit position and/or reduce cost of borrowing for investments thus, boosting their productivity. Furthermore, the observed positive effect could also be due to subsidies decreasing risk aversion which ensures that the farm productivity adjustment is stronger as farmers may be more willing to expand capital and adopt novel technologies. For the cases where insignificant or a negative effect of subsidies after decoupling is still observed, this could be due to either insignificant market imperfections (credit problems) in the agricultural sector (e.g., Sweden) or partial decoupling[20] (e.g., Greece) or the combination of the two factors. For example, if farm credit problems are insignificant, there is minor or no gain from subsidies through the credit channel.[21] Partial decoupling means that a share of subsidies is kept coupled with the introduction of decoupled payments in 2005/2006 which may lead to efficiency losses due to persistence of production distortions offsetting partly or fully the gains from alleviation of market imperfections (i.e., the investment-induced productivity gains).

6 Summary and conclusions

The focus of the paper is on evaluating the link between CAP subsidies and total factor productivity of the EU commercial farms. The paper also documents aggregate productivity differences across the EU Member States and FADN farm types (sectors) using micro data. We build a structural model of the unobserved productivity incorporating directly the effects of farm subsidies and adapt the semi-parametric estimation algorithm proposed by Olley and Pakes (1996) to estimate the parameters of production functions within the FADN farm-type samples, for each of the EU-15 countries, and for the period 1990/1995– 2008. We control for differences in the economic environment across narrowly defined spatial units and model productivity as a non-parametric function of investment and state variables, including as additional control farm subsidies which greatly enhances our ability to obtain consistent estimates of the production function parameters and thus, back out unbiased TFP measures at farm level.

[20]With the introduction of the decoupled payments, countries could still allocate part of the total subsidy envelope to coupled payments such as arable crop payments, sheep and goat payments, suckle cow premium, etc. (EUR-Lex, 2003). Examples of countries which maintained a significant level of coupled payments include Austria, France, Greece, Italy, and Portugal.

[21] Other factor (land and labour) market imperfections might also affect both the level and rate of change of productivity.

We aggregate farm productivity measures by country and farm type and find some evidence that aggregate productivity level and growth systematically differ between the north and south European country sets. Our correlation analysis, for each of the EU-15 countries, clearly demonstrates the link between CAP subsidies and farm total factor productivity. We find negative correlation between subsidies and farm productivity in the period before the decoupling reform was implemented; after decoupling, in 2005/2006, the correlation between subsidies and productivity is more nuanced as in several countries it turned positive. Theoretically the link between subsidies and productivity is determined by the net effect of allocative and technical efficiency losses and the investment-induced productivity gains caused by the interaction of market imperfections with subsidy. We do not identify the two effects separately; we can only infer their relative importance from the net effect. A caveat we need to acknowledge is that our results are based on the EU-15 samples which consist of the more developed economies in Europe where market failures are less pronounced. The results might be different for the samples of the less developed new Member States where *ceteris paribus* the credit alleviation effect of subsidies might be stronger.

Our findings are consistent with the literature emphasising the inefficiencies of public subsidisation of production and at the same time lend support to the EU policy for decoupling of CAP subsidies. The results suggest that the decoupled payments are less distortive and enhance productivity which is consistent with the WTO agenda. From the food security perspective the evidence indicates possible improvement in future food availability through increasing productive capacity of EU agricultural sector. The 2011 European Commission proposal for the post-2013 CAP suggests maintaining the decoupled subsidies system after 2013 which would likely ensure continued future enhancement of EU farm productivity. Our analyses suggest that the positive productivity effect of subsidy decoupling could be induced by correcting for inefficiencies in the agricultural sector. However, one should be careful in drawing conclusions regarding general welfare implications from this, since the analysis do not account for distortions of taxation funding the subsidy.

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Table 1 Summary statistics

Country	Investment (s.d.)	Capital (s.d.)	Labour (s.d.)	Materials (s.d.)	Output (s.d.)	Subsidies (s.d.)	Exits (No.obs.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Belgium	43.7	881.9	5131	76.3	141.0	23.0	0.14
	(282.5)	(686.8)	(2618)	(67.4)	(106.3)	(14.8)	(14482)
Denmark	112.8	1429.5	4932	201.6	327.3	27.0	0.26
	(526.6)	(1763.7)	(4713)	(208.2)	(332.1)	(28.5)	(17543)
Germany	84.1	1841.1	5336	113.4	172.4	31.2	0.12
	(2497.1)	(5461.1)	(7990)	(199.7)	(285.9)	(78.3)	(74777)
Greece	3.0	173.9	4301	14.8	38.2	7.1	0.20
	(43.9)	(115.4)	(2518)	(13.0)	(22.4)	(10.5)	(17883)
Spain	32.8	304.7	3399	29.3	60.3	8.2	0.15
	(1251.6)	(2188.1)	(1776)	(39.5)	(57.9)	(11.9)	(58502)
France	58.5	658.8	3821	67.7	117.2	21.5	0.13
	(587.1)	(1220.8)	(2533)	(52.9)	(91.4)	(22.0)	(93420)
Ireland	49.6	817.6	3711	42.9	73.1	16.2	0.16
	(240.3)	(649.8)	(1361)	(25.3)	(46.3)	(14.9)	(8230)
Italy	57.0	901.1	4701	30.9	73.1	7.9	0.29
	(950.7)	(1735.9)	(2805)	(41.7)	(84.2)	(53.7)	(99433)
Luxembourg	26.7	1047.6	3697	69.5	117.0	31.8	0.08
	(145.6)	(471.1)	(1260)	(36.8)	(56.3)	(22.7)	(4807)
Netherlands	111.1	1588.7	6358	182.2	314.9	16.7	0.17
	(765.3)	(1700.5)	(6191)	(206.8)	(326.5)	(24.2)	(17290)
Austria	16.1	370.6	4178	33.6	63.6	19.6	0.06
	(63.6)	(190.5)	(1499)	(19.6)	(32.7)	(11.9)	(17248)
Portugal	3.6	152.4	5176	30.1	49.2	8.3	0.21
	(56.2)	(119.9)	(2826)	(27.5)	(37.3)	(17.1)	(12343)
Finland	13.4	322.4	4577	67.0	83.0	34.7	0.10
	(64.5)	(219.1)	(2450)	(50.1)	(70.1)	(24.8)	(7176)
Sweden	55.1	818.4	3725	98.1	132.1	28.3	0.11
	(424.3)	(832.4)	(1750)	(75.0)	(111.0)	(26.8)	(6645)
UK	33.5	990.3	5488	95.1	142.4	31.6	0.17
	(299.6)	(781.2)	(3687)	(82.2)	(132.3)	(32.1)	(38405)

Notes: Mean and standard deviation (s.d.) are reported for each variable. All monetary variables are measured in 2000 (thousands of) Euros. Labour is measured in total full-time equivalent hours worked annually The average annual exit rate (Exits) capture farms exiting the sample both because of exiting production and because of the sampling rules. Total number of observations (No.obs.) is also reported.

Table 2 Production function coefficients and productivity estimates

Country	β_m (s.e.)	β_l (s.e.)	β_k (s.e.)	Adj.R^2 (No.obs.)	TFP index (TFP growth)
(1)	(2)	(3)	(4)	(5)	(6)
Belgium	0.68	0.24	0.08	0.98	1.10
	(0.03)	(0.04)	(0.02)	(10693)	(-0.63)
Denmark	0.72	0.26	0.08	0.97	1.02
	(0.02)	(0.02)	(0.02)	(10697)	(-0.06)
Germany	0.84	0.17	0.07	0.93	1.05
	(0.01)	(0.01)	(0.01)	(54037)	(+0.63)
Greece	0.59	0.22	0.07	0.99	0.73
	(0.02)	(0.02)	(0.02)	(11957)	(+0.43)
Spain	0.60	0.26	0.07	0.98	1.09
	(0.01)	(0.02)	(0.01)	(32121)	(+1.98)
France	0.74	0.21	0.08	0.97	1.01
	(0.01)	(0.01)	(0.01)	(71274)	(+0.24)
Ireland	0.80	0.07	0.05	0.98	1.23
	(0.02)	(0.02)	(0.02)	(6088)	(-0.59)
Italy	0.62	0.20	0.07	0.98	1.10
	(0.01)	(0.01)	(0.01)	(56977)	(+2.05)
Luxembourg	0.68	0.24	0.10	0.99	0.99
	(0.03)	(0.03)	(0.02)	(3799)	(+0.63)
Netherlands	0.70	0.27	0.11	0.98	1.04
	(0.01)	(0.02)	(0.01)	(12800)	(-0.61)
Austria	0.62	0.20	0.12	0.99	1.36
	(0.02)	(0.02)	(0.02)	(13228)	(+1.44)
Portugal	0.64	0.20	0.07	0.97	0.96
	(0.02)	(0.03)	(0.01)	(8341)	(+1.89)
Finland	0.68	0.16	0.11	0.93	1.67
	(0.03)	(0.02)	(0.02)	(5364)	(-0.78)
Sweden	0.87	0.11	0.06	0.95	1.20
	(0.03)	(0.02)	(0.01)	(4626)	(-0.47)
UK	0.80	0.22	0.08	0.94	0.99
	(0.01)	(0.02)	(0.01)	(27680)	(+0.18)

Notes: TFP index is an aggregate productivity measure in relative levels; TFP growth is the aggregate annual percentage change. Aggregated production function coefficients and Adj.R^2 are reported. Total number of observations (No.obs.) reported is from the second-step estimated samples.

Table 3a Correlation between subsidies and productivity, full samples

Country	TFP index		TFP growth	
	Pre-reform	Post-reform	Pre-reform	Post-reform
(1)	(2)	(3)	(4)	(5)
Belgium	-0.272	-0.250	-0.015	+0.024
	(0.000)	(0.000)	(0.024)	(0.032)
Denmark	+0.160	+0.206	+0.018	+0.024
	(0.000)	(0.000)	(0.087)	(0.055)
Germany	-0.526	-0.477	+0.014	+0.027
	(0.000)	(0.000)	(0.079)	(0.000)
Greece	-0.068	-0.034	-0.081	-0.015
	(0.000)	(0.000)	(0.000)	(0.183)
Spain	-0.471	-0.402	-0.022	+0.022
	(0.000)	(0.000)	(0.000)	(0.028)
France	-0.539	-0.507	-0.027	+0.013
	(0.000)	(0.000)	(0.000)	(0.000)
Ireland	-0.502	-0.278	-0.029	+0.025
	(0.000)	(0.000)	(0.059)	(0.041)
Italy	-0.324	-0.304	+0.013	+0.026
	(0.000)	(0.000)	(0.129)	(0.000)
Luxembourg	-0.175	-0.032	-0.047	+0.057
	(0.000)	(0.246)	(0.001)	(0.059)
Netherlands	-0.648	-0.504	-0.015	+0.018
	(0.000)	(0.000)	(0.143)	(0.375)
Austria	-0.060	+0.080	-0.022	+0.028
	(0.000)	(0.000)	(0.045)	(0.063)
Portugal	+0.253	+0.266	-0.047	+0.001
	(0.000)	(0.000)	(0.002)	(0.063)
Finland	-0.162	+0.049	+0.003	+0.070
	(0.000)	(0.023)	(0.868)	(0.004)
Sweden	-0.222	+0.006	-0.011	+0.016
	(0.000)	(0.766)	(0.572)	(0.500)
UK	-0.337	-0.206	-0.038	+0.041
	(0.000)	(0.000)	(0.000)	(0.001)

Notes: Spearman rank correlation coefficients are reported. In parentheses below each coefficient reported is Prob > |t| for the test of the null: subsidies and productivity are independent.

Table 3b Correlation between subsidies and productivity, decoupling subsamples

Country	TFP index		TFP growth	
	Pre-reform	Post-reform	Pre-reform	Post-reform
(1)	(2)	(3)	(4)	(5)
Belgium	-0.294	+0.063	-0.031	+0.076
	(0.000)	(0.011)	(0.106)	(0.010)
Denmark	+0.167	+0.251	-0.016	+0.049
	(0.000)	(0.000)	(0.181)	(0.019)
Germany	-0.592	-0.447	-0.031	+0.037
	(0.000)	(0.000)	(0.000)	(0.017)
Greece	-0.081	+0.055	-0.128	+0.017
	(0.000)	(0.107)	(0.002)	(0.107)
Spain	-0.482	-0.144	-0.026	+0.024
	(0.000)	(0.000)	(0.015)	(0.028)
France	-0.565	+0.010	-0.034	+0.051
	(0.000)	(0.135)	(0.000)	(0.019)
Ireland	-0.542	-0.153	-0.031	+0.030
	(0.000)	(0.005)	(0.022)	(0.061)
Italy	-0.337	-0.258	-0.008	+0.028
	(0.000)	(0.000)	(0.302)	(0.000)
Luxembourg	-0.186	+0.069	-0.111	+0.068
	(0.087)	(0.055)	(0.012)	(0.032)
Netherlands	-0.654	-0.324	-0.026	+0.020
	(0.000)	(0.000)	(0.038)	(0.093)
Austria	-0.108	+0.178	-0.028	+0.048
	(0.000)	(0.030)	(0.022)	(0.056)
Portugal	+0.225	+0.290	-0.041	+0.100
	(0.000)	(0.000)	(0.009)	(0.062)
Finland	-0.238	+0.111	-0.005	+0.032
	(0.000)	(0.041)	(0.370)	(0.051)
Sweden	-0.247	+0.191	-0.032	+0.035
	(0.000)	(0.016)	(0.139)	(0.472)
UK	-0.372	-0.180	-0.055	+0.067
	(0.000)	(0.000)	(0.072)	(0.018)

Notes: Spearman rank correlation coefficients are reported. In parentheses below each coefficient reported is Prob > |t| for the test of the null: subsidies and productivity are independent.